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Data Acquisition Technologies and Sensor Networks

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Abstract

In warehouses, forklifts are one of the most utilized equipment for transporting cargos from one place to another. In a study by Occupational safety and Health Administration – USA (OSHA), it was observed that the most of hazardous accidents happening in warehouses are due to forklifts [1]. We explored the reasons behind these accidents and found that, they are caused due to human errors, so to give a solution to this problem we have come up with an approach to automate the whole process of transporting cargo within warehouse using sensor networking and image processing. Our approach is very simple, we use Arduino as a hardware to link our other hardware components with our gesture recognition algorithm and make them work according to the generated output. Currently we have targeted to automate the movement of logistics from one rack level to another based on the hand gesture of the user.

Introduction

The forklift is one of the tools that is most frequently used in a warehouse. These strong industrial trucks efficiently lift and convey freight. However, using any industrial machine, regardless of how strong a forklift may be, comes with some risks. Forklifts cause 61,800 minor injuries, 34,900 serious injuries, and 85 fatalities annually, according to the Occupational Safety and Health Administration [1]. There are reportedly one million forklifts in use, and they all run manually. Hence, there are high chances that majority of accidents are caused due to human error. If a solution to all these risks is not given, then it may result into more serious injuries and deaths. In addition to that as we know that these forklifts are run manually, the drivers are needed to be trained in operating forklifts and should have authorized license. This costs the organization time as well as money.

Automating the whole process of lifting logistics from one place to another or one rack level to another can act as an optimized solution. Thus, in this case, we have attempted to automate the process using our understanding of sensors and image analysis. We have developed a computerized pipeline in which user will indicate rack level using their fingers. For instance, if users indicate two fingers, then it means the cargo should be loaded at rack level 2. Once this level is recognized, the output is passed to the Arduino where it is processed and given to the respective motor sensor to move the forklift shaft at such an angle that it can reach the indicated level precisely.

The basic working of our model uses a built-in laptop camera fetching the live feed of human hand gesture giving the number of fingers detecting by gesture recognition. Once that is recognized next step is to store the output and pass it to Arduino. This is done on a local server where it acts as a medium to exchange and store information. Following to that, the Arduino fetches the information from the local server and passes it to other hardware. For instances if the number of fingers detected are between 1 - 5 then that information is passed to the servomotor and then it moves angularly between 0 - 180 degrees based on the number detected.

To visualize the results and get additional information for further analysis, we have created an online real-time dashboard and have also used LCD to locally display the current rack level on which the forklift is transferring the cargo. In addition to that to make system more accessible, we have created a cloud server where from which user can globally access the system and also get real time and past information from the dashboard.

Local Server

1. Overview

There are six components connecting to the local server as shown in the Figure 1.

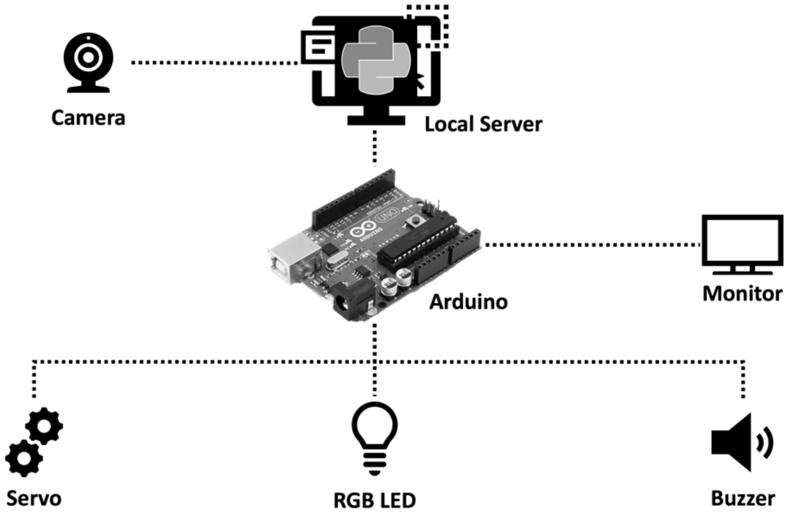

Figure 1: Topology of local server

2. Components

The project is built on a model which deals with easy to access functionality for the customers who want to ship the packets and the products with the help of the logistics department. The model works in such a way that the customer keeps the shipment that is being shipped on a platform. The customer then signals a gesture in front of the camera and then the shipment is sent on one of the levels assigned with the gesture by changing the angle of the lever. Each level is assigned with the gesture in such a way that the shipment is sent to a particular location set and desired by the customer.

The prototype of the project uses the following components:

2.1. Built-in Laptop Camera

Figure 2: Webcam camera

The Built-in laptop camera helps in capturing the gesture and recognizing the number of fingers that are being held up in front of the camera by the customer which is being calculated by an algorithm called as 'Otsu' algorithm. This algorithm first captures the gesture, draws an outline around the gesture and then subtracts the background from the gesture. It then further converts the captured image with the gesture from regular image to black & white image which in turn helps to calculate the number of points on the gesture with the outline of the gesture. This helps in recognizing the number of fingers being held up and further proceed with the next steps of the model.

2.2. Servomotor

Figure 3: Servo motor

The servomotor changes its angle from 0 degree to 180 degrees depending on the gesture by the customer. The angle of the lever changes at every 36 degrees angle of the servomotor which is assigned to five different levels in the warehouse.

2.3. LCD Display

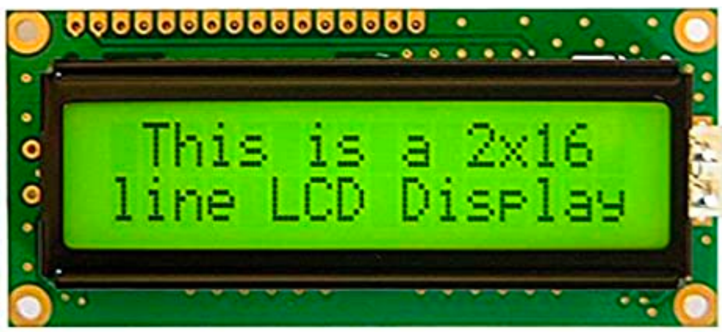

Figure 4: LCD Display

The LCD is used to display the number of fingers that are held up, the angle of the servomotor and the color of the RGB Led. If there is no gesture or the number of fingers is more than 5 then it will only display the number of fingers that are being held up and in case of no gesture it will display 0.

2.4. RGB LED

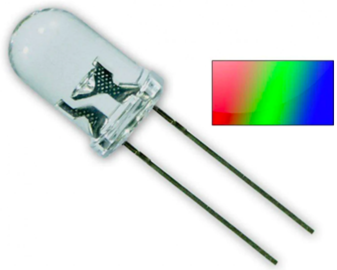

Figure 5: RGB LED

The color of the RGB Led changes for every level in the warehouse from 1-5 depending on the gesture by the customer which has also been pre-assigned to each level.

2.5. Buzzer

Figure 6: Buzzer

The buzzer is used for the confirmation of the gesture if the gesture and the number of fingers that are being held up in front of the camera is from 1-5. If there is no gesture or the number of fingers is more than 5 then the buzzer would not make any sound indicating that the input gesture is not within the desired range.

2.6. Breadboard & Arduino

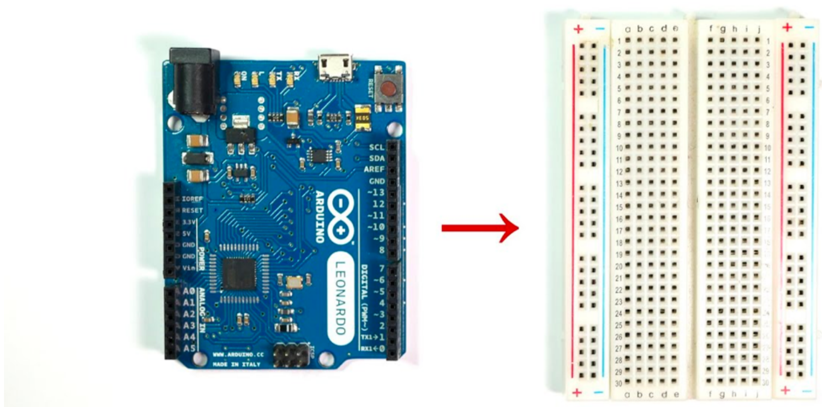

Figure 7: Arduino UNO (left) and breadboard (right)

All the components including the servomotor, the RGB Led, the buzzer and the LCD display are connected to the breadboard and the built-in laptop camera is connected with the Arduino which is connected to the breadboard.

3. Process

The prototype of the project uses a built-in camera from the laptop which acts as the camera used for capturing the input from the customers through the gestures that they make in front of the camera. In order for the camera to recognize the gesture signaled by the customer, the camera allocates a certain number of points in front of the hand of the customer starting from the bottom of the palm to the tip of the fingers. The prototype uses an algorithm implementing in Python for the camera called an 'Otsu' algorithm that assigns four number of points to each finger, from the bottom to the tip of the finger, of the hand, held by the customer in front of the camera. So, when a gesture is being signaled by the customer in front of the camera, the camera captures the gestures, and the algorithm starts calculating the number of points on one or more fingers when in turn helps the algorithm in recognizing the number of fingers that are being held up by the customer in front of the camera. So, for example, if the customer holds up two fingers in front of the camera, the algorithm will then quickly calculate the number of points which in this example is 8 points. The algorithm would then recognize that two fingers are being held up in front of the camera and further actions would then proceed based on the gesture of the customer.

All the other components such as servomotor, RGB Led, LCD display, etc., are all connected on the breadboard with the Arduino. The gesture input captured by the camera can only take the input to be from 1 - 5 fingers. Each gesture is assigned to a different level in the warehouse and each level is also indicated by the different color on the RGB Led. The buzzer would also help and make a sound indicating that the packet or the product is placed on the platform and is set to go to the desired level of the warehouse. If there is no gesture or the number of fingers held up by the customer in front of the camera is more than 5 fingers, then the color of the RGB Led would turn to red and there would also be no sound made by the buzzer.

Similarly, each and every level is connected with the servomotor. The servomotor acts as a tool to change the angle of the lever which is connected to five different levels in the warehouse. The servomotor changes the angle of the lever at every level from 1-5. Since there are five different levels, the servomotor changes from 0 degree to 180 degree. So, whenever the customer signals a gesture in front of the camera, it is automatically changing the angle of the servomotor according to the input gesture. The level changes at every 36 degrees of the servomotor. So, when the lever is at level

1 the servomotor angle would be at 36 degrees. At level 2 the servomotor angle would be at 72 degrees. At level 3 the servomotor angle would be at 108 degrees. At level 4 the servomotor angle would be at 144 degrees and at the last level i.e., level 5 the servomotor angle would be at 180 degrees. The LCD displays the number of fingers that are being held up in front of the camera, the angle of the servomotor and the color of the RGB Led. Furthermore, all the data is being store in the database about how many a times each level has been used by the customer, how the long the gesture is held up for in front of the camera or what was the angle of the lever when the shipment was being sent to a particular level during the process. So, for example, if a customer wants his/her shipment to be shipped on the level 3 in the warehouse, he/she would hold up 3 fingers in front of the camera. The camera would recognize the 3 fingers being held up and change the angle of the servomotor to 108 degrees which would make the RGB Led to turn green and also the buzzer would make a sound to confirm the process. This would in turn make the lever to take the shipment to level 3. This data would finally also be stored in the database.

Remote Access

There are three main components when it comes to remote access which are remote server, local server, and remote client displayed in Figure 8.

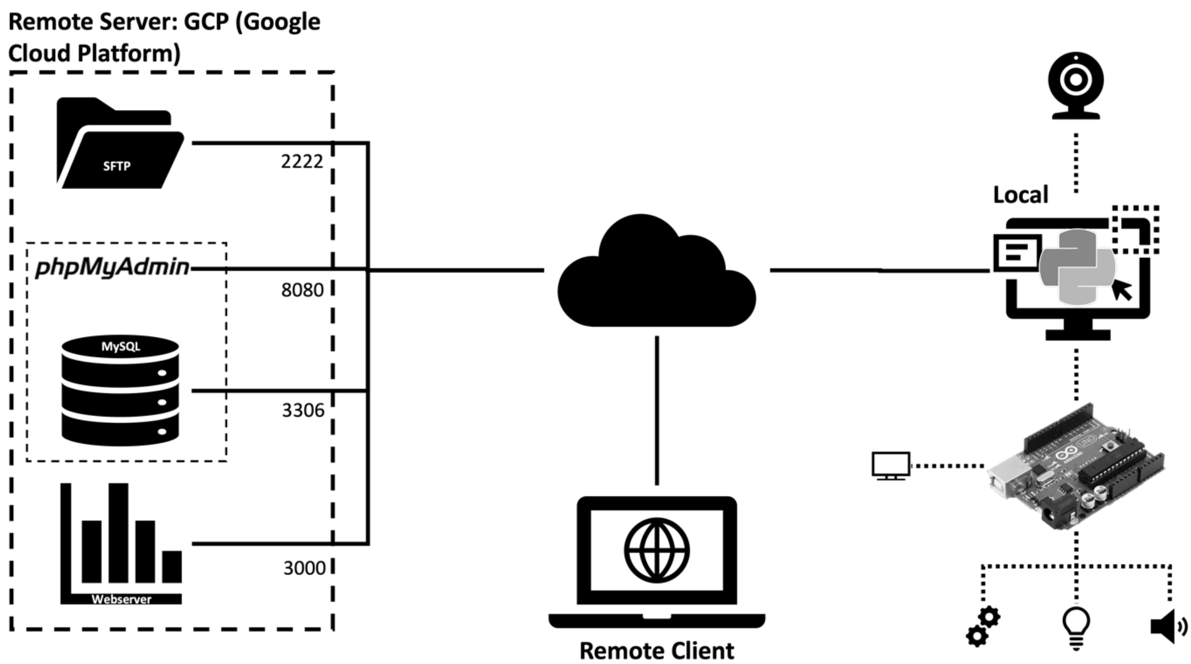

Figure 8: Network topology of the system

1. Remote server

The server is created on a service in Google Cloud Platform called Computer Instance. It is a server with a Linux OS named Debian OS. In that we deployed four applications/services with Docker which are Secure File Transfer Protocol (SFTP), phpMyAdmin, MySQL and Webserver.

1.1. Secure File Transfer Protocol (SFTP)

The purpose of file transfer protocol is to upload files into our server for instance, a picture for the webserver. It can be accessed by using remote server's ip address and defined SFTP port (2222) combining with username and password.

1.2. phpMyAdmin

It is a webpage used as human machine interface to manage our database. It can be access with remote server's IP address with port 8080. It makes user easier to test MySQL query to create tables, insert table, managing users and so on in production stage.

1.3. MySQL

MySQL database is a SQL database that we used to store our data from the sensors. The port that we used is the default port which is 3306. A table named sensor is created with 9 columns as detail listed on the table below and in Figure 9.

Table 1: Sensor table

Column	Description	Data type	Data range
eid	Event id. It automatically increases every time we insert new data.	SERIAL	[1, 2, 3, …]
date	Date that event occurs	DATE	
time	Time that event occurs	TIME	
finger	Number of fingers	INT	[1, 2, 3, 4, 5]
led_r	Red color code of RGB led	INT	[0, …, 255]
led_g	Green color code of RGB led	INT	[0, …, 255]
led_b	Blue color code of RGB led	INT	[0, …, 255]
servo_angle	An angle of the servo	INT	[0, …, 180]
servo_level	The level of the shelves	INT	[1, 2, 3, 4, 5]

←T→			eid	date	time	finger	led_r	led_b	led_g	servo_angle	servo_level
Edit	Copy	Delete	1282	2022-12-07	09:07:31	0	0	0	0	0	0
Edit	Copy	Delete	1283	2022-12-07	09:07:32	2	0	255	0	72	2
Edit	Copy	Delete	1284	2022-12-07	09:07:34	3	0	0	255	108	3
Edit	Copy	Delete	1285	2022-12-07	09:07:40	4	255	255	255	144	4
Edit	Copy	Delete	1286	2022-12-07	09:07:40	3	0	0	255	108	3
Edit	Copy	Delete	1287	2022-12-07	09:07:41	2	0	255	0	72	2
Edit	Copy	Delete	1288	2022-12-07	09:07:41	0	0	0	0	0	0
Edit	Copy	Delete	1289	2022-12-07	09:07:42	1	255	0	0	36	1
Edit	Copy	Delete	1290	2022-12-07	09:07:43	0	0	0	0	0	0
Edit	Copy	Delete	1291	2022-12-07	09:07:44	1	255	0	0	36	1
Edit	Copy	Delete	1292	2022-12-07	09:07:44	0	0	0	0	0	0
Edit	Copy	Delete	1293	2022-12-07	09:08:01	1	255	0	0	36	1

Figure 9: An example of data in sensor table

1.4. Webserver

The webserver is based on an open-source platform called Grafana. It provides a varies of charts and data visualization tools to our users. It can be accessed by every computer connecting to internet which we call remote clients. To use the application, users must access by using the server's IP address with port 3000. There are two pages which are level and sensor. As shown in Figure 10 Level is for observing on which level of the forklift currently in and also the history. As per the sensor page, the users can spectate in each component. For example, the color of RGB LED, number of fingers and angle of the servo as illustrated in Figure 11 and Figure 12.

Figure 10: Level page

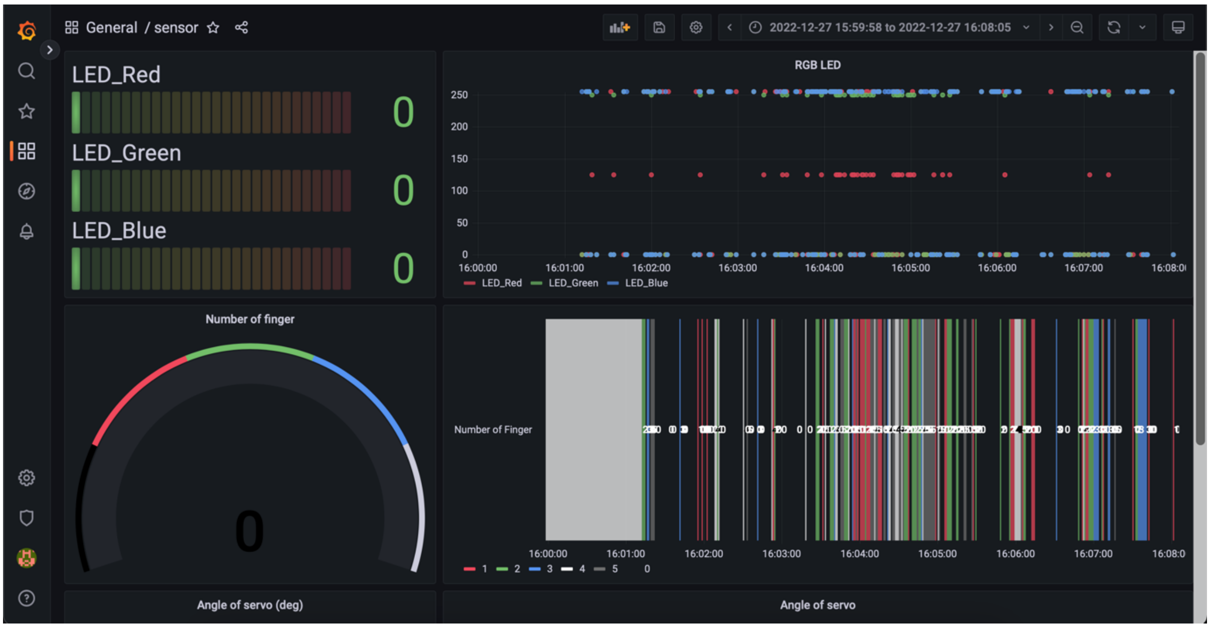

Figure 11: Sensor page with RGB LED and number of fingers information

Figure 12: Sensor page with number of fingers and angle of servo information

2. Local server

The purpose of local server is to acquire data from Arduino and camera then it acts as an exchanger between the sensors and the remote server when the number of fingers changes.

3. Remote Client

Users are represented by remote client. It is used to access remote server anywhere in the world as long as the clients have internet connection.

Pipeline

In Figure 13, these are the steps of the forklift system.

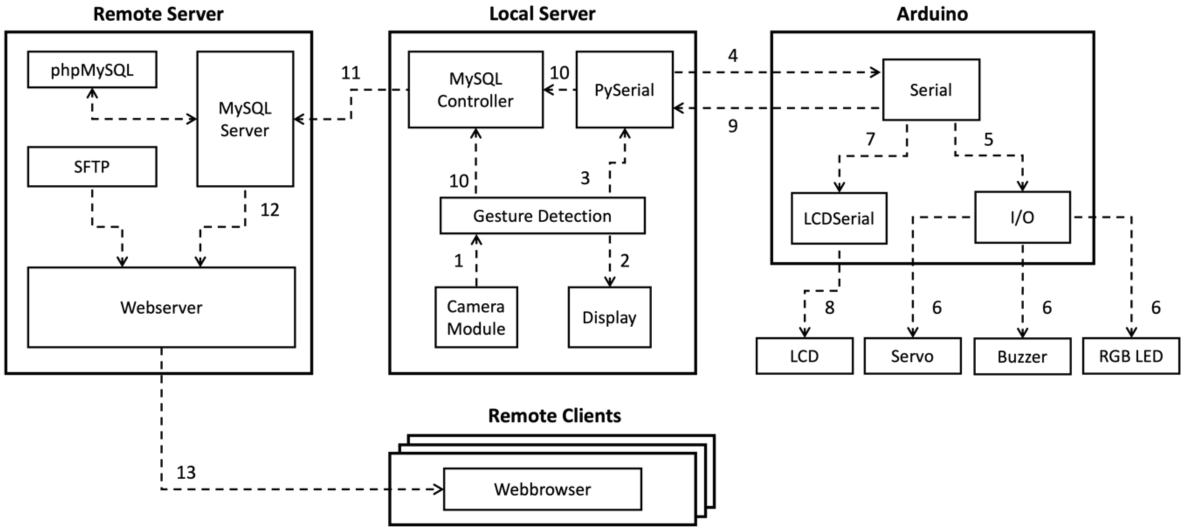

Figure 13: Pipeline of the system

Firstly, gesture detection uses sequence images capturing from the camera and sends to the monitor to display. Secondly the number of fingers is sent to Arduino via serial connection using PySerial module. Next the number of fingers is used as an input for the algorithm to control the color of RGB LED, buzzer, and servo angle. Then the information of level and angle are displayed on LCD. The data of color and angle is transmitted through serial to local server then to MySQL server on remote server as same as the number of fingers. Webserver queries the data from MySQL server and display in time-series graph, gauges, and text for remote clients to visualize in both real-time and record data.

Conclusion and Future Aspect

In conclusion, this project will provide a high level of security, speed, and accuracy in shifting packages from a rack to another, which will create a great impact on business as it is going to be a one-time investment for organizations and a long-term revenue generation plan. Due to the reason that it is not necessity to invest their time and money behind training employees for driving forklifts and shifting cargos. In addition, there will be no human intervention, so the work would be done more optimally and efficiently.

For future work, it is planned to add speech recognition module to our pipeline, so users, without using their hand gesture, can also work with our system. We will also add a language module to speech recognition, in case of the users does not know how to speak English then also, they can operate by speaking in their mother tongue. Furthermore, driverless fully automated forklifts will be added to the system so that we can computerized the whole process of picking, sorting, and placing the goods on the correct racks indicated by the users.

Bibliography

[1] C. Paulausky, "Death by Forklift is Really the PITs," 01 09 2013. [Online]. Available: https://ohsonline.com/Articles/2013/09/01/Death-by-Forklift-is-Really-the-PITs.aspx?m=1. [Accessed 24 12 2022].